Army Research Laboratory

Real-time Kinematics Global Positioning System (GPS) Operation and Setup Method for the Synchronous Impulse Reconstruction (SIRE) Radar

by Francois Koenig and David Wong

ARL-TN-0393 **May 2010**

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Adelphi, MD 20783-1197

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Real-time Kinematics Global Positioning System (GPS) Operation and Setup Method for the Synchronous Impulse Reconstruction (SIRE) Radar

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REPORT DOCUMENTATION PAGE						*Form Approved* *OMB No. 0704-0188*

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1. REPORT DATE *(DD-MM-YYYY)* May 2010	**2. REPORT TYPE** Final	**3. DATES COVERED (From - To)**
4. TITLE AND SUBTITLE Real-time Kinematics Global Positioning System (GPS) Operation and Setup Method for the Synchronous Impulse Reconstruction (SIRE) Radar		**5a. CONTRACT NUMBER**
		5b. GRANT NUMBER
		5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S) Francois Koenig (ARL) and David Wong (NVESD)		**5d. PROJECT NUMBER**
		5e. TASK NUMBER
		5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) U.S. Army Research Laboratory ATTN: RDRL-SER-U 2800 Powder Mill Road Adelphi, MD 20783-1197		**8. PERFORMING ORGANIZATION REPORT NUMBER** ARL-TN-0393
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		**10. SPONSOR/MONITOR'S ACRONYM(S)**
		11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT

The report provides a description of the Real-time Kinematics (RTK) global positioning system (GPS) operation and setup procedures to provide real-time position data for the Synchronous Impulse Reconstruction (SIRE) radar. These accurate position data allow proper real-time focusing of radar images and preserves image quality on a moving platform.

15. SUBJECT TERMS

SIRE radar, real time kinematic global positioning system, differential global positioning system

16. SECURITY CLASSIFICATION OF:			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON** Francois Koenig
a. REPORT Unclassified	**b. ABSTRACT** Unclassified	**c. THIS PAGE** Unclassified	UU	22	**19b. TELEPHONE NUMBER (*Include area code*)** (301) 394-0856

Standard Form 298 (Rev. 8/98)
Prescribed by ANSI Std. Z39.18

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1. Introduction

This report provides a description of the Real-time Kinematics (RTK) global positioning system (GPS) operation and setup procedure to provide real-time position data for the Synchronous Impulse Reconstruction (SIRE) radar. Section 1 provides background information on Differential GPS (DGPS) and the application of RTK operation. Section 2 describes the step-by-step recommended operating procedure for RTK implementation for the SIRE radar. Section 3 gives an example of results obtained with RTK operation at Yuma Proving Ground (YPG), AZ, and a comparison of these results with those obtained with post-processing DGPS. The last section provides a summary of the results.

DGPS is an enhancement to GPS that calculates an error correction vector based on the difference between the known location of the base station and the perceived location of the base station from the current received satellite information. This correction vector can then be sent to the rover receiver to correct its estimated location. For optimum performance, both the base station and the rover should be present in the same general location observing the same satellite configuration. DGPS can be achieved either through real-time telemetry links between a base and a rover or through post-processing of the data. In a previous report (*1*), a description of DGPS operation and the post-processing method used during earlier SIRE radar field tests was presented. Real-time methods include (1) a medium frequency beacon differential service, (2) an L-Band satellite differential service, (3) an FM sub-carrier differential service, or (4) an on-site RF telemetry link. All of the real-time services have a coverage area and a range limitation and require a local radio/receiver to obtain the transmitted service. Method 4 requires the user to operate a transmitter in addition to the radio/receiver. Generally, DGPS systems can achieve a resolution of a meter or better when monitoring the Coarse Acquisition (C/A) or Precise (P) code phase.

RTK is a special form of DGPS that monitors not only the signal code but also the signal carrier. Since the carrier wavelength is about 100 times smaller than the signal code wavelength, RTK performance is about 100 times better than standard DGPS. The combination of the code phase and the carrier phase can achieve a resolution of a few centimeters. While there is increased resolution from monitoring the carrier, there is also an increased risk of error due to carrier ambiguities. The carrier ambiguities result from the inability of the GPS to determine the integer number of carrier cycles between the satellite and the receiver. In effect, we have a measuring stick with fine markings but no labels. Numerous studies have produced algorithms encoded within the GPS to resolve this carrier-cycle integer ambiguity within seconds of startup and with varying degrees of accuracy (*2*).

The RTK method described in this report uses an onsite RF telemetry link. That link consists of two radio modems that we use for local GPS communications, a transmitter for the base station GPS, and a receiver for the rover GPS. The radio modems are NL 2400 transceivers from RF Neulink, Inc. The NL 2400 operates at a frequency of 2.4 GHz and 200 mW of power, with a range of up to 2 km, line-of-sight distance. The two GPS units that we use for DGPS are Z-Surveyor receivers from Ashtech. They feature 12 parallel channels, which receive the C/A code phase and full wavelength carrier phase measurement on the L1 frequency (1575 MHz), and P-code phase and full wavelength carrier phase on both the L1 and the L2 frequency (1227 MHz).

2. Recommended Operating Procedure

The following operating procedures provide consistent RTK GPS data for the SIRE radar data collection (*3*). GPS messages are transmitted from the base station to the rover receiver at a 1-Hz rate. The rover applies these messages to its own received position information and outputs the differentially corrected position information (as well as time) at a 10-Hz rate. The streaming output is sent to the PC over a serial line and tabulated by the real-time software as well as saved to a disk file. The PC also receives time tag data from the rover over another serial line, indicating a radar data collection event. The real-time software correlates the radar time tag with the streaming GPS time and provides an accurate location of the radar for that collection event. In addition, raw position data are recorded at a 0.1-s rate onto a flash card in the GPS units to be downloaded later and differentially post-processed, if needed.

We should note here that a simple correlation of radar time tag with streaming time from Universal Transverse Mercator (UTM) position data will produce a registration error of 14 or more seconds. The reason is that the time tag generated in the Z-Surveyor from the event trigger (radar) is in GPS time and the streaming time from the Z-Surveyor is in Coordinated Universal Time (UTC). The difference between the two formats is an integer number of “leap” seconds inserted into UTC time since 1980 (*4*, *5*). As of January 2009, the UTC time is slower than the GPS time by 15 s (*6*). This subtle offset in times has been included in the real-time SIRE software to avoid registration errors.

2.1 Initial Transceiver Configuration

The NL 2400 transceivers need to be programmed initially for their designated mode of operation. This configuration only needs to be done once since it is stored in nonvolatile memory in the device. We use RF Neulink’s provided utility to configure the base NL 2400 as a transmitter/server and the rover NL 2400 as receiver/client. The resultant configuration windows displayed on the PC are shown in figure 1.

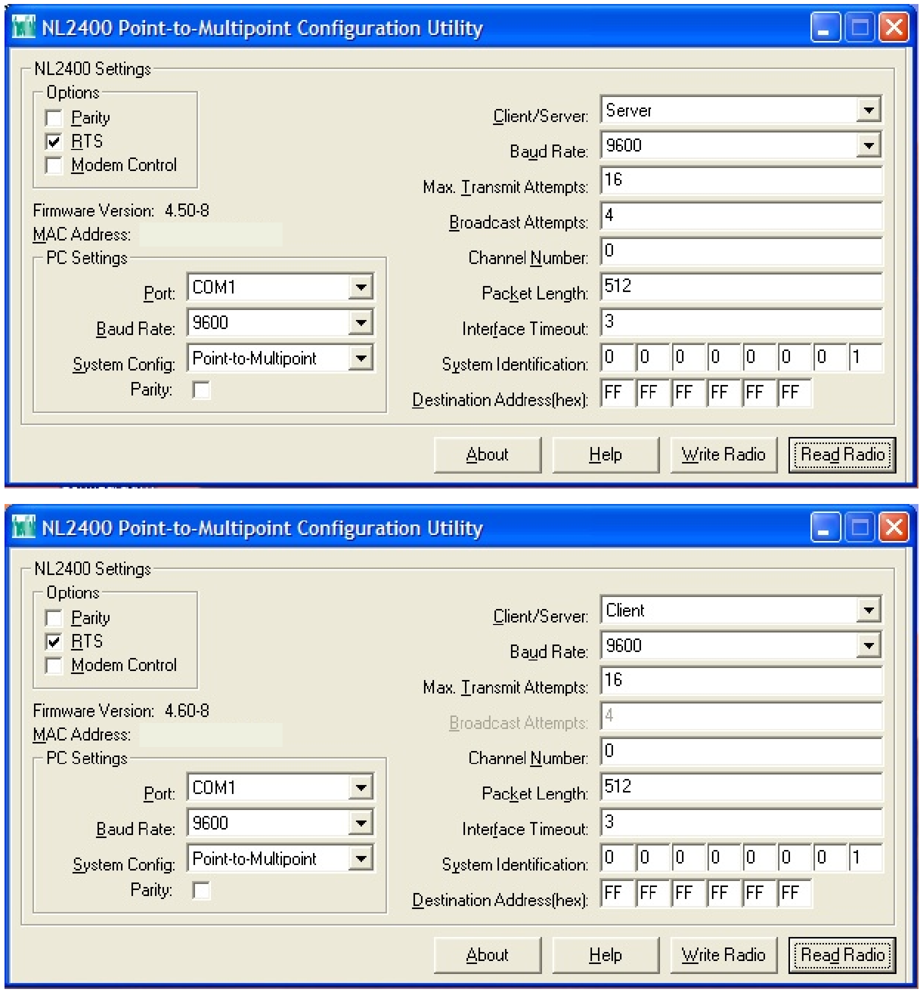

Figure 1. NL 2400 configuration utility window for server (base) and client (rover).

2.2 Cable Interface between Z-Surveyor and NL 2400

Serial RS-232 cables used to connect the Z-Surveyor to a PC serial port were purchased from Ashtech. These cables contain a 7-pin Fischer connector for the Z-Surveyor port and a 9-pin D connector for the PC port. To communicate between the Z-Surveyor and the NL 2400, an additional null modem adapter was needed and built. The complete interconnect wiring diagram between the Z-Surveyor and the NL 2400 is shown in figure 2.

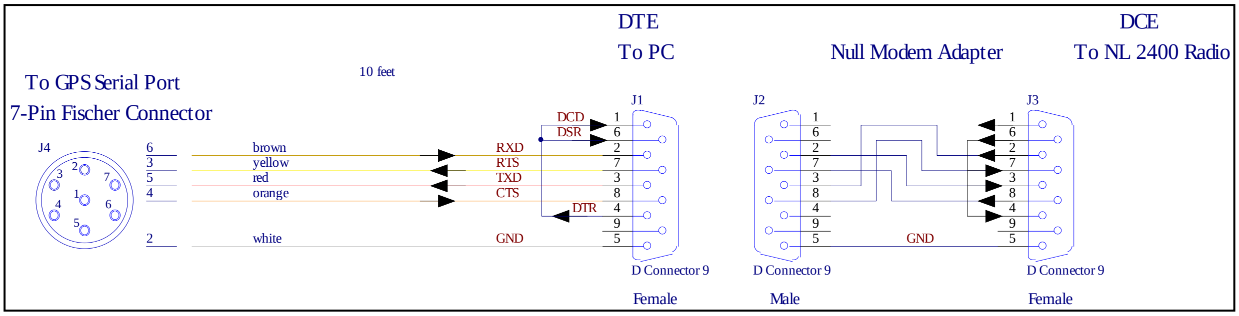

Figure 2. NL 2400 to GPS receiver interconnect cables.

2.3 Obtain an Accurate Base Station Location

Before we can begin to transmit accurate position data from the base station, we need to know exactly where it is located. The simplest way of obtaining the location coordinates is to locate the base station at a previously surveyed position. In this case, the GPS antenna would be placed exactly over the survey point and its previously determined GPS coordinates would be used. Unfortunately, survey points are not always available near a desirable base station location, especially for this RTK method, which requires line of sight between the base and rover. If a prior survey has not been performed, we need to record base station position data for 30 min or more and post-process the data against a known base station. Continuously operated reference stations (CORS) are listed at http://www.ngs.noaa.gov/CORS/ and their GPS RINEX2 data can be downloaded for our recorded time period. We perform the post-processing technique described in reference 1, where the nearest CORS station is treated as the known "base" and our Z-Surveyor base station becomes the "rover." The centroid of the post-processed Z-Surveyor location coordinates becomes the GPS coordinate used in the RTK base station entry.

2.4 Base Station RTK GPS Setup

A summary of the base station interconnect is provided in figure 3.

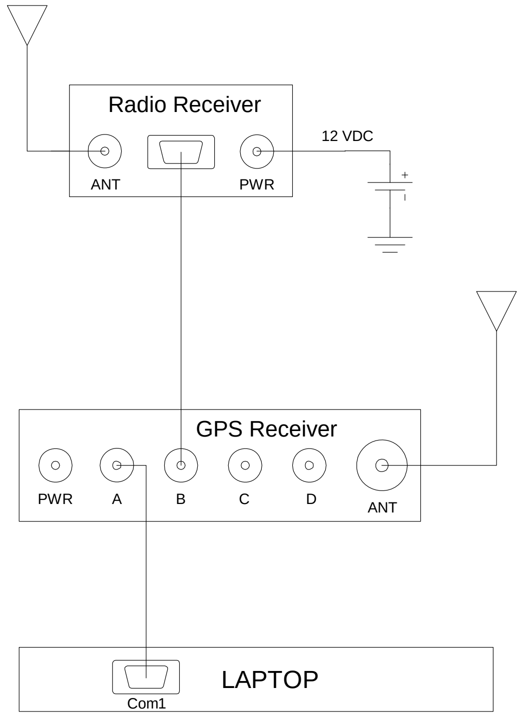

Figure 3. Interconnect diagram of the RTK base station.

1. Set up the base station GPS antenna on a level tripod and measure the height of the antenna above ground (figure 4).

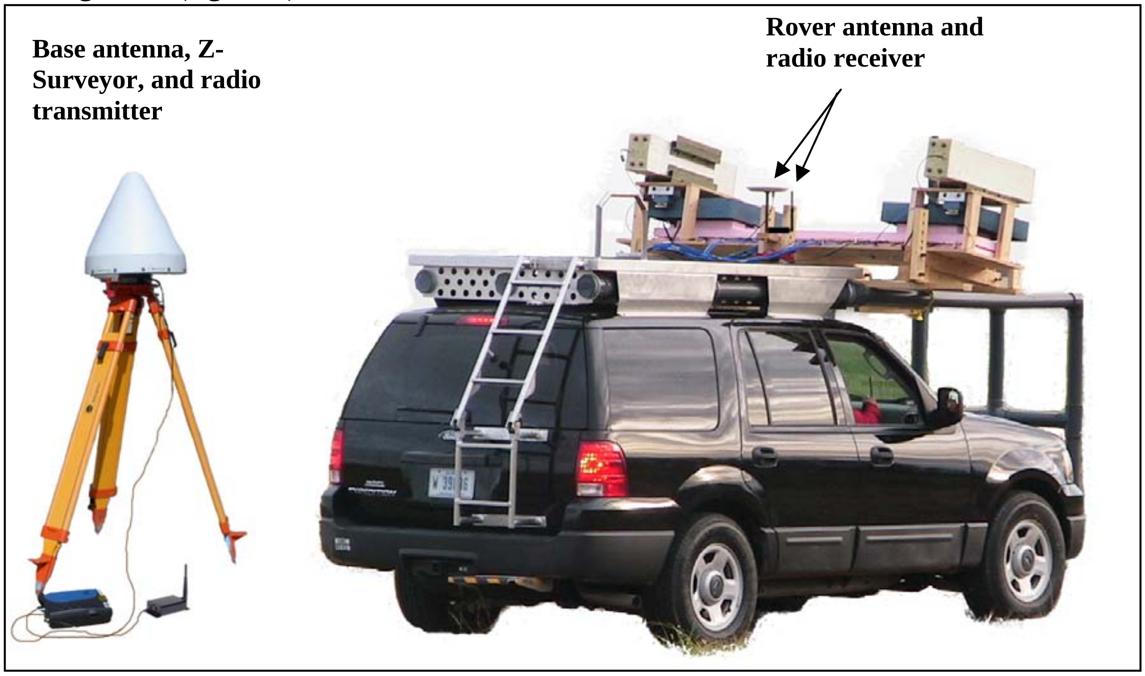

Figure 4. Example of base station setup with Z-Surveyor and NL 2400 radio transmitter (left), and rover antenna with NL 2400 radio receiver mounted on the roof of mobile platform with Z-Surveyor stored inside the vehicle (right).

2. Set up the NL 2400 base radio transmitter on a tripod such that it has a continuous line of sight to the rover receiver.

3. Install a charged battery into the base Z-Surveyor unit (figure 5).

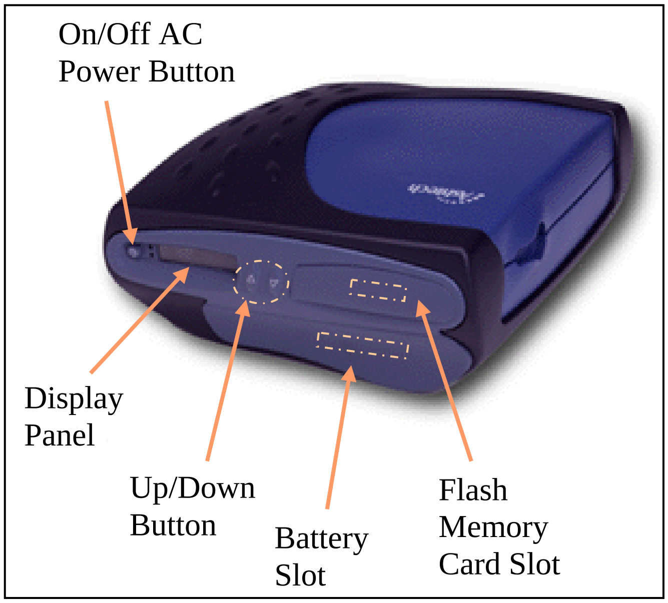

Figure 5. The front (left) and rear (right) panels of Z-Surveyor unit.

4. Connect the base Z-Surveyor to the GPS antenna.

5. Turn on Z-Surveyor by pushing the power button on the left of the unit. A “sysinfo” message will display on the front panel for a few seconds. Connect Port A of base Z-Surveyor to the laptop with the serial cable.

6. Connect the NL 2400 radio transmitter serial port to Port B of the base Z-Surveyor with a serial cable.

7. Connect the NL 2400 power jack to a 12 V battery using the power cable. The Pwr LED should glow green.

8. Login to the laptop and run **evaluate** (also called **eval32).**

9. Select “Connect to GPS Receiver with last settings”. Com1 is the port operating at 9600 baud.

10. Check the sky chart by clicking its icon at the top of the window.

11. Check the indicator panel by clicking its icon at the top of the window.

12. Select the terminal by clicking its icon at the top of the window.

13. In the Terminal window,

    a. Select “menu” and select “Turn off all NMEA[*] messages” (for display). Hit send.

    b. Select “type” and under “type”, enter the following sequence of commands:

select $PASHS, CLM	Hit send. (Format flash card. Returns “passed” after about 4 min.)
select $PASHS, RST	Hit send. (Reset receiver to factory defaults.)
select $PASHS,REC,S	Hit send. (Stop recording.)
select $PASHS, ELM, 9	Hit send. (Set RTK Base mask to 9°, recommended mask angle)
select $PASHS, POS, ddmm.mmmmmmm,N,dddmm.mmmmmmm,W,aaaaa.aaa	Hit send. (Phase center of base antenna)[†]
select $PASHS, RNG, 4	Hit send. (Store all format files.)
select $PASHS, CPD, OUT, 1	Hit send. (Output CPD solution to card and/or serial port.)
select $PASHS, CPD, MOD, BAS	Hit send. (Instruct the Base receiver to operate in CPD (RTK) mode.)
select $PASHS, CPD, PRT, B	Hit send. (Set port “B” to output DBEN[‡] message.)
select $PASHS, CPD, PED, 1	Hit send. (Transmit DBEN at 1 s.)
select $PASHS, CPD, PEB, 10	Hit send. (Broadcast Base station location every 10 s.)
select $PASHS, SIT, BASE	Hit send. (Label the current receiver as “Base.”)
select $PASHS, RCI, 0.1	Hit send. (Collect data at 0.1 s.)
select $PASHS,REC,R	Hit send. (Start recording.)
select $PASHS, SAV, Y	Hit send. (Save settings.)

    For checking current status:

select $PASHQ, CPD	Hit send. (Check current settings.)
select $PASHQ, RAW	Hit send. (Check parameters related to raw data.)
select $PASHQ, POS	Hit send. (Check current position message.)

    c. Close the sky chart and indicator panel and then reopen them. Check for five or more satellites in the sky chart and that data are updating in the indicator panel.

    d. Close the evaluate program, close the laptop, and disconnect the serial cable from the laptop. Verify that the red record LED is still flashing on the Z-Surveyor.

14. Check the NL 2400 radio transmitter to verify that the Tx LED flashes red.

Note: The 85 MB flash card will fill after 4 or 5 h of recording. A fully charged battery should last at least 5 h.

---

[*] NMEA = National Marine Electronics Association.

[†] ddmm.mmmmmmm = latitude in degrees, decimal minutes, for example, 3902.1686167.
dddmm.mmmmmmm = longitude in degrees, decimal minutes, for example, 07657.1895667.
aaaaa.aaa = height in meters, for example, 43.479.

[‡] DBEN is an Ashtech proprietary data format.

2.5 Base Station RTK GPS Initialization Files

One can avoid the tedious task of manually entering the previously described GPS receiver command strings by preparing an initialization file ahead of time. One should prepare an ASCII file in a text editor and save it with a .gps extension in the Ashtech Evaluate installation directory under the Receiver subdirectory. An example file is shown in figure 6.

```
;RTK Base station setting for Site 1
$PASHS,RST
$PASHS,REC,S
$PASHS,ELM,9
$PASHS,POS,3902.1686167,N,07657.1895667,W,43.479
$PASHS,RNG,4
$PASHS,CPD,OUT,1
$PASHS,CPD,MOD,BAS
$PASHS,CPD,PRT,B
$PASHS,CPD,PED,1
$PASHS,CPD,PEB,10
$PASHS,SIT,BASE
$PASHS,RCI,0.1
$PASHS,REC,R
$PASHS,SAV,Y
```

Figure 6. Initialization file for base station RTK GPS.

The procedure for running the initialization file is as follows:

1. Login to the laptop and run **evaluate.**
2. On the startup menu, select “Cancel” instead of “Connect to GPS Receiver with last settings”.
3. Click on the connect icon at the top left or select “GPS” and then “Connect..” from the pull-down menu.
4. Check “Initialize from file:” and select the previously saved initialization file.
5. Select “Connect” and **evaluate** will run the initialization file.

2.6 Base Station RTK GPS Shutdown Sequence

The following steps outline how to initiate the base station RTK GPS shutdown sequence:

1. Turn off Z-Surveyor unit.
2. Remove the flash card. **Warning:** Never pull out a flash card while it is recording (the red LED is flashing).
3. Remove the Z-Surveyor battery and put it into the charger.

4. Disconnect the battery from the NL 2400 radio transmitter and charge it.
5. Disconnect all cables and store.
6. Remove the GPS antenna from the tripod and stow.

2.7 Rover RTK GPS Setup

A summary of the rover interconnect is provided in figure 7.

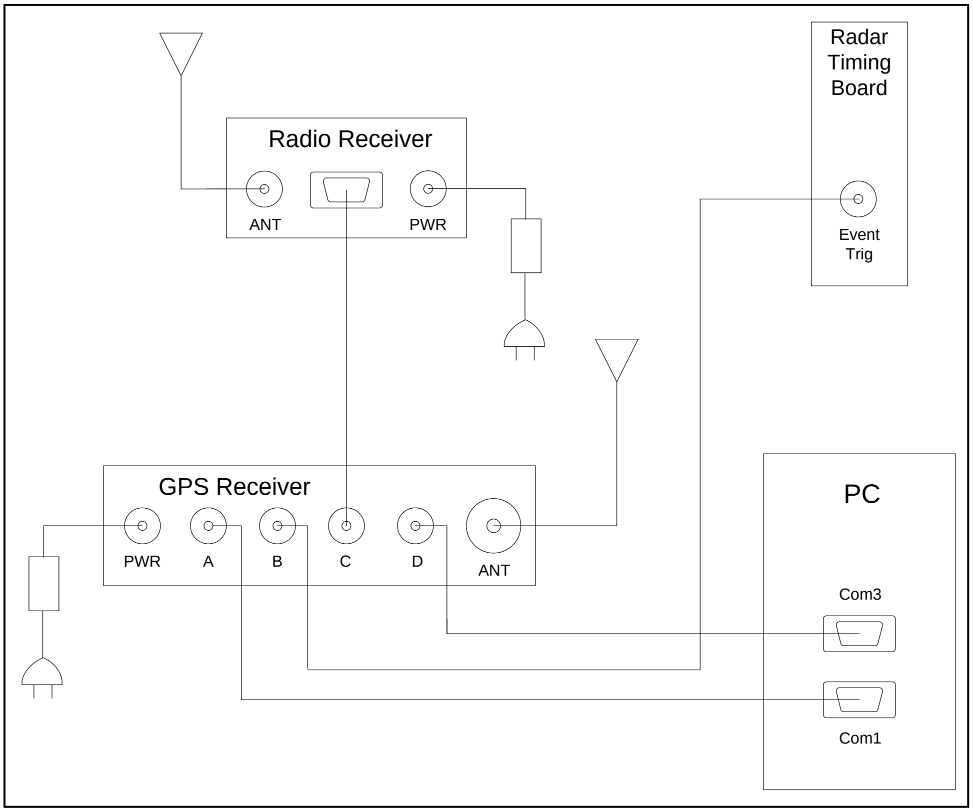

Figure 7. Interconnect diagram of the RTK rover.

Follow these steps to set up the RTK rover:

1. Install a charged battery into the rover Z-Surveyor unit. The battery will provide uninterrupted power to the Z-Surveyor unit if the inverter shuts down.
2. Install the rover NL 2400 radio receiver and antenna in a location that will maintain continuous line of sight to the base NL 2400 radio transmitter.
3. Connect the serial output of the NL 2400 radio receiver to port “C” of the rover GPS receiver.

4. Connect the 12 V power adapter to the power jack of the NL 2400 receiver. Plug the other end of the power adapter into an AC power source. The NL 2400 Pwr LED should now glow green.

5. Bring up the SIRE program on the PC. Turn GPS settings ON. A series of commands are automatically sent to Z-Surveyor from the PC. Depending on the version of the SIRE software, the commands in step 6 may be sent automatically to the GPS receiver. They have been included here to complete the user's understanding of the rover setup.

6. Perform the following commands in the SIRE GPS window:

select $PASHS, CLM	Hit send. (Clear and format card.)
select $PASHS, RST	Hit send. (Reset receiver to factory defaults.)
select $PASHS,REC,S	Hit send. (Stop recording.)
select $PASHS, SPD, C, 5	Hit send. (Set port "C" to 9600 baud for radio link.)
select $PASHS, SPD, D, 6	Hit send. (Set port "D" to 19200 baud to stream RTK data to PC.)
select $PASHS, CPD, MOD, ROV	Hit send. (Instruct the rover receiver to operate in CPD (RTK) mode.)
select $PASHS, CPD, OUT, 1	Hit send. (Output CPD solution to card and/or serial port.)
select $PASHS, SIT, ROVE	Hit send. (Label the current receiver as "Rover.")
select $PASHS, RNG, 4	Hit send. (Store all format files.)
select $PASHS, RCI, 0.1	Hit send. (Collect data at 0.1 s.)
select $PASHS, NME, TTT, A, ON	Hit send. (Set and output time tag information on port "A". Note: This requires E option on the receiver and an event trigger pulse at port B.)
select $PASHS, NME, UTM, D, ON	Hit send. (Set and output NME UTM information on port "D.")
select $PASHS, NME, PER, 0.1	Hit send. (Set NME message period to 0.1 s.)
select $PASHS,REC,R	Hit send. Start recording.)
select $PASHS, SAV, Y	Hit send. (Save settings.)

For checking current status:

select $PASHQ, CPD	Hit send. (Check current settings.)
select $PASHQ, RAW	Hit send. (Check parameters related to raw data.)
select $PASHQ, POS	Hit send. (Check current position message.)

7. Check the NL 2400 radio receiver to verify that the Rx LED flashes green.

The rover Z-Surveyor will continue to collect data on its flash card until stopped or shut off. It continues recording even if the software is stopped. **Warning:** Never pull out the flash card while recording (the red LED is flashing).

2.8 Rover RTK GPS Shutdown Sequence

The following is the shutdown sequence for the rover RTK GPS:

1. Turn off the Z-Surveyor unit.

2. Remove the flash card.

3. Remove the battery and put it into its charger.

4. Disconnect power from the NL 2400 radio receiver.

3. Results

We conducted a SIRE radar data collection at YPG, AZ, during the summer of 2008. A series of runs took place simultaneously using the RTK GPS procedures described in this report as well as the collection technique for post-processing described in reference 1. A plot of the northing and easting coordinates of the two techniques for one of the Yuma runs is shown in figure 8. It reveals a high degree of overlay in position of the RTK and post-processing methods. In fact, the maximum difference in corresponding values between the two methods was 8 mm in easting and 9 mm in northing for this run.

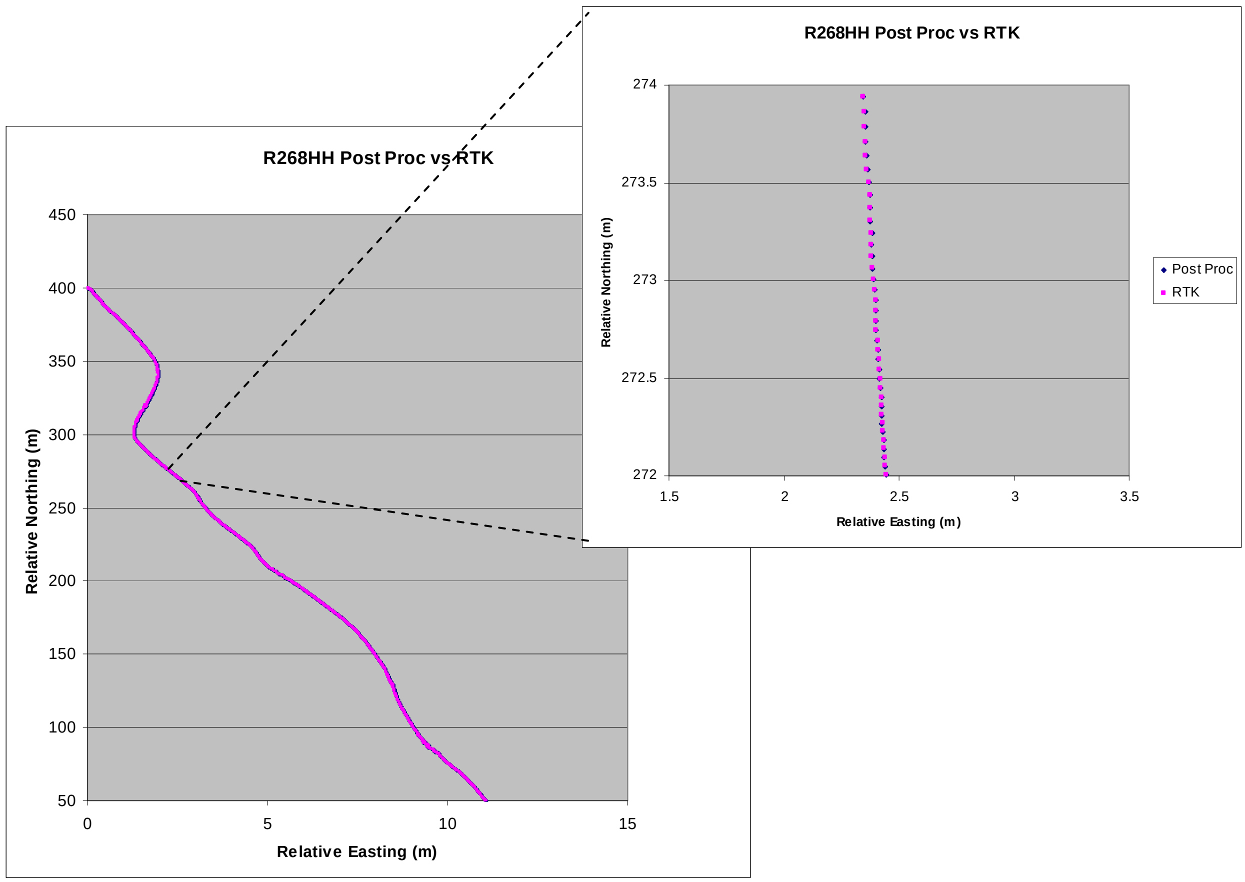

Figure 8. Plot of post-processing rover coordinates vs. RTK rover coordinates for a SIRE run at YPG.

4. Conclusions

We obtained centimeter accuracy of position data through the proper use of a real-time DGPS solution. A stationary (base station) GPS receiver was set up in the test area to collect data and transmit it over a radio link to the rover. Another GPS receiver (rover) was installed on the SIRE platform with a radio receiver to receive correction data from the base station. The radio link provides the DGPS solution to the rover in real time. We have shown that position data collected through the radio link compares favorably to the post-processing solution obtained through GrafNav software. Either DGPS configuration provides the essential positioning information needed to allow SIRE radar data to be focused in a known coordinate system. The RTK radio link configuration provides that positioning information in real time.

5. References

1. Koenig, F.; Wong, D. *Differential Global Positioning System (DGPS) Operation and Post-Processing Method for the Synchronous Impulse Reconstruction (SIRE) Radar*; ARL-TN-0281; U.S. Army Research Laboratory: Adelphi, MD, June 2007.

2. Kaplan, E. D. (ed.) *Understanding GPS Principles and Applications*; Artech House: Boston, MA, 1996.

3. Ressler, M.; Nguyen, L.; Koenig, F.; Smith, G. Synchronous Impulse Reconstruction (SIRE) Radar Sensor for Autonomous Navigation. *Army Science Conference*, Nov 2006.

4. GPS Timing Data & Information. United States Naval Observatory. http://tycho.usno.navy.mil/gps_datafiles.html (accessed May 2010).

5. USNO GPS Time Transfer. United States Naval Observatory. http://tycho.usno.navy.mil/gpstt.html (accessed May 2010).

6. Leap Seconds. United States Naval Observatory. http://tycho.usno.navy.mil/leapsec.html (accessed May 2010).

List of Symbols, Abbreviations, and Acronyms

C/A	Coarse Acquisition
CORS	continuously operated reference stations
DGPS	differential GPS
GPS	global positioning system
P	Precise
RTK	Real-time Kinematic
SIRE	Synchronous Impulse Reconstruction
UTC	coordinated universal time
UTM	Universal Transverse Mercator
YPG	Yuma Proving Ground

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